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AUTHOR	Provasnik, Stephen J.; Young, Benjamin O.
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ABSTRACT

This paper investigates the relationship of teacher quality to student mathematics achievement at the eighth grade level based on the findings from the National Assessment of Education Progress (NAEP, 2000). It looks for circumstantial evidence of teacher sorting by testing the hypothesis that "better teachers are more likely to teach better scoring students." The NAEP 8th grade mathematics student scale score is used to identify the characteristics of students associated with student performance in mathematics, and Item Response Theory (IRT) is used to compute a teacher quality scale based on teachers' responses to NAEP background questions. Factors influencing student achievement, teacher quality, and the relationship between teacher quality and factors influencing student achievement are discussed based on the research findings. (KHR)

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The relationship of teacher quality to student mathematics achievement at the 8th-grade: Findings from the National Assessment of Education Progress (2000)

Stephen J. Provasnik
Benjamin O. Young

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Perspectives and Theoretical Framework

We know from previous research with state and national longitudinal data that teacher characteristics considered markers of "teacher quality" are associated with student achievement. On average, students with highly qualified teachers score higher on standardized tests than students with less qualified teachers (Ferguson and Womack 1993; Monk and King 1994; Ehrenberg and Brewer 1994; Ferguson and Ladd 1996; Rowan, Chiang, and Miller 1997; Goldhaber and Brewer 1997a, 1997b, 2000). We also know from a recent Texas case study (Hanushek, Kain, and Rivkin 2001) that particular student characteristics have a stronger effect on teachers moving to another school than do salary differentials. Specifically, we know that schools "serving large numbers of academically disadvantaged, black or Hispanic students tend to lose a substantial fraction of teachers each year" (Ibid., 2). The combination of these findings raise the question of whether the most qualified teachers tend to move to schools with better performing students. If true, this would imply that teachers are systemically sorting themselves in ways that leave disadvantaged students with both the mediocre and worst teachers. Or is teacher quality not a factor in teachers' moves to other schools because teachers of all qualifications move in about the same proportions?

Stephen J. Provasnik is a senior research analyst, and Benjamin O. Young is a research associate at American Institutes for Research in Washington, D.C. The authors can be reached at sprovasnik@air.org and byoung@air.org.

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This paper takes this question as a starting point to analyze teacher quality in relation to student performance. This paper, however, represents only the first step toward answering this question. Using the 2000 National Assessment of Educational Progress (NAEP) 8th-grade mathematics assessment, we looked for circumstantial evidence of teacher sorting by testing the hypothesis that "better teachers are more likely to teach better scoring students" through a three-step method. First, using NAEP 8th-grade mathematics student scale scores, we identified the characteristics of students associated with student performance in mathematics. Second, we used Item Response Theory (IRT) to compute a teacher quality scale based on teachers' responses to NAEP background questions. Third, we regressed this scale on the student and school characteristics found to be associated with student achievement scores.

Data Source

NAEP is the largest representative national survey to assess what students know and can do in mathematics. It also administers background questionnaires to the schools, teachers, and students that are part of the NAEP sample. Responses to these questionnaires provide an abundance of information about school policies, school and teacher characteristics, and students' family and background. The 2000 NAEP 8th-grade mathematics assessment was administered to approximately 16,000 students in 744 public and private schools nationwide, making this dataset especially useful for exploring our research hypothesis.

The reason for using the 2000 NAEP 8th-grade mathematics assessment to examine this study's hypothesis is that its teacher background questionnaire is an especially rich source of information about individual teacher's educational background, teacher training, preparation, and self-confidence in teaching specific mathematical skills/competencies. The 2000 NAEP is perhaps the most comprehensive source of teacher background data available with assessment scores from a nationally representative sample of students. This particular questionnaire

provides a broader set of variables than any other NAEP subject assessment including the 2000 NAEP 4th-grade mathematics assessment.

The NAEP dataset does, however, have some important limitations. As is the case with all sampled data, the data collected in the 2000 8th-grade mathematics assessment are subject to sampling error. To correct for sampling error, our analysis used weighted estimates to make our estimates nationally representative and used AM software to compensate for the cluster and strata design effects. However, because NAEP is designed to collect data from a nationally representative sample of students—not a nationally representative sample of teachers—the weighted estimates actually are for 'teachers who taught 8th-grade mathematics to the nationally representative sample of students' (as opposed to a truly 'nationally representative sample of teachers'). In addition, this dataset does not contain an exact measure of student socio-economic status. The 2000 NAEP student background questionnaires did not ask students to provide information on parental income because significant flaws have been found in such information provided in the past by elementary and junior high school students. Unfortunately, the omission of this question means the dataset does not contain a potentially important influence on student achievement.

Measures

The measures used in this analysis can be grouped into three categories: teacher quality factors, student characteristics, and school characteristics.

Teacher quality characteristics

Several variables were used to assess teacher quality. In order to measure a teacher's mathematics qualifications, a composite in-field teaching variable was created from the following teacher background questions: Are you certified in middle/junior high school or secondary mathematics (t040504)?, Do you have a mathematics (t040703) or mathematics

education major (t040704) for your undergraduate degree?, Do you have a mathematics (t040803) or mathematics education major (t040804) for your graduate degree? Our composite variable coded teachers from 0 to 4, with 0 being teachers who answered 'no' to these three questions[1], 1 those who were certified in middle/junior high school or secondary mathematics but did not major in mathematics at the undergraduate or graduate level, 2 those who majored in mathematics but were not certified in middle/junior high school or secondary mathematics, 3 those with an undergraduate major in mathematics and certified in middle/junior high school or secondary mathematics, and 4 those with a graduate major in mathematics and certified in middle/junior high school or secondary mathematics. We combined data on certification and major to create this composite variable because past research indicates that both are important determinants of student outcomes (Goldhaber & Brewer 1997a, 1997b, and 2000)

To identify those teachers who by virtue of being brand new teachers lacked sufficient experience to be highly effective teachers we used the NAEP dataset's question on the number of years of teaching experience (t040301) to create a dummy variable for 2 years or less of teaching experience. We based the creation of this variable also on prior research, which has indicated that, while there is no positive or linear relationship between years of experience teaching and student achievement, there is evidence that brand new teachers are typically less effective than teachers with at least 5 years of teaching experience (Darling-Hammond, 2000).

In order to measure a teacher's range and depth of study of subject matter content, we created a composite variable from a set of questions pertaining to teachers' academic and

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[1] Because of the high percentage of teachers who did not answer t040504, we also coded as 0 any teachers who (1) said they were certified in elementary or middle school/junior high school general education (t040501), elementary mathematics (t040506) or another type of certification recognized by the state in which you teach (t040505) and (2) did not say 'yes' or 'no' to middle/junior high school or secondary mathematics (t040504). The logic for this is that some teachers answered 'yes' to the certification question that applied to them and then skipped the other certification questions instead of responding 'no'. Coding 0 in this way thus allows us to maximize the sample of teachers who could be considered as not certified for 8th-grade mathematics without including any teachers in states were certification was not offered (with whom a valid comparison is not possible). Even so, missing certification data reduced the original sample of 18,153 to 14,019.

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professional training in specific mathematics concepts. Specifically teachers were asked if they had one or more college or university courses in methods of teaching elementary mathematics (t056901) or professional development covering the same subject (t0569b1). Similar questions were asked about number systems and numeration (t056902 and t0569b2), measurement in mathematics (t056903 and t0569b3), geometry (t056904 and t0569b4), probability/statistics (t056905 and t0569b5), and calculus (t056906 and t0569b6). Positive responses were coded 1, while negative responses were coded zero. Our composite variable was computed as the sum of all such responses and ranges from 0 to 12.

In order to measure teacher's exposure to general and subject-specific teaching methods, we used questions that asked (yes/no) whether teachers ever studied: estimation (t057001), problem solving in mathematics (t057002), the use of manipulatives (t057003), the use of calculators in mathematics instruction (t057004), understanding students' thinking about mathematics (t057005), gender issues in the teaching of mathematics (t057006), and teaching students from different cultural backgrounds (t057007). These variables were coded 1 for a "yes" and 0 for "no". The composite variable was computed as the sum of these variables and ranges from 0 to 7.

In order to measure teachers' self-confidence in teaching specific mathematical skills/competencies, we used categorical variables from the 2000 data files that encode whether teachers feel "very well prepared," "moderately prepared," "not very well prepared," or "not at all prepared" to use manipulatives in mathematics instruction (t075107) and to teach each of the following: (a) number sense, properties, and operations (t075101); (b) measurement (t075102); (c) geometry and spatial sense (t075103); (d) data analysis, statistics, and probability (informal introduction of concepts) (t075104); (e) algebra and functions (informal introduction of concepts) (t075108); (f) estimation (t075105); and (g) mathematical problem-solving (t075106).

These variables were coded 0 for "Not at all prepared," 1 for "Not very well prepared," 2 for "Moderately well prepared," and 3 for "Very well prepared." We computed an index variable by summing these variables for part of our analysis. This variable ranged from 3 to 24. Multiple responses or responses such as "I don't know" were coded as missing.

Student performance and characteristics

Average NAEP scores are calculated from NAEP plausible value variables to measure student performance on the 2000 8th-grade assessment. AM software allows us to correctly weight the results and simultaneously account for the cluster and strata design effects of NAEP's complex sample design.

The student characteristics included in this analysis include race/ethnicity (drace), level of current math class (m813701), presence of an Individualized Education Plan (iep), English language proficiency (lep), free/reduced priced lunch eligibility (slunch1), parental education (pared), and eligibility for Title 1 funding (title1). We recoded the variable m813701 into 1 for "8th-grade mathematics," 2 for "Pre-Algebra," and 3 for "Algebra, 2nd- year Algebra, or Geometry." Multiple responses or responses such as "I don't know" were coded as missing.

School characteristics

The school factors include school type (pubpriv), geographic region (cenreg), school location (tol7), and percent of students eligible for free or reduced-price lunch (c043801). We recoded c043801 into 1 for "0-5%," 2 for "6-25%," 3 for "26-50%," 4 for "51-75%," and 5 for "76-100%." CENREG is coded 1 for "Northeast," 2 for "Midwest," 3 for "Southeast," and 4 for "West." The variable tol7 is coded 1 for "Large city," 2 for "Mid-size city," 3 for "Urban fringe large city," 4 for "Urban fringe mid-size city," 5 for "Large town," 6 for "Small town," and 7 for "Rural." AM software allowed us to dummy-code each of these variables for use in our analysis.

Procedures

First, to identify those student factors that are highly positively or negatively correlated with NAEP scale scores, we estimated an ordinary least-squares (OLS) regression model using student score as the dependent variable. We controlled for teacher quality and school factors, using the variables described above under Measures. The results can be interpreted straightforwardly as the change in math score associated with a particular student characteristic when holding other student, teacher, and school factors constant. The general equation for this model can be shown as:

$$Y_i = \delta + (\beta_1 T_1 + \beta_2 T_2 \ldots + \beta_i T_i) + (\beta_1 S_1 + \beta_2 S_2 \ldots + \beta_i S_i) + (\beta_1 X_1 + \beta_2 X_2 \ldots + \beta_i X_i) + e_i$$

Where:

Y = Student mathematics score
$T_{1\text{-}i}$ = Teacher Characteristics
$S_{1\text{-}i}$ = School Characteristics
$X_{1\text{-}i}$ = Student Characteristic
δ = constant term
e_i = error term

Second, to create a variable for teacher quality, we used Item Response Theory (IRT)[i] to scale teachers' responses to the background questions on college major, certification in middle school/secondary mathematics, years of teaching experience, range and depth of subject matter study, and self-confidence in teaching specific mathematical skills/competencies. IRT is regularly used to scale students' assessment responses to NAEP items such that student responses are normally distributed with a standard deviation of 1. The underlying assumption of IRT is that all items partially measure some latent trait that cannot be measured directly (e.g., mathematical reasoning) and that correct responses indicate some degree of the respondent's latent ability. (IRT can also take into account the fact that some correct responses are lucky guesses and that some wrong answers are simple errors that do not reflect the respondent's true

latent ability.[2]) IRT calculates a "difficulty" level for each item based on the proportion of correct responses and the relationships among the responses to all the items related to the same trait. This "difficulty" value is also known as the "location parameter" because it assigns the item response to a location along the IRT-calculated scale. In this way, IRT provides a means of placing items and students along the same continuum.

The application of IRT to teacher responses on background questions is likewise meant to place teacher background questions and teachers along the same continuum. The benefit of this methodology is that it allows "quality" to be defined on the basis of background "item difficulty" rather than assumptions about what characteristics are the best measures of the latent trait of teacher quality. The use of IRT with teacher responses assumes several things:

(1) that these questions measure some degree of the latent trait of teaching quality;

(2) that different characteristics (e.g., having completed a college course in calculus versus having a masters degree in mathematics) represent different degrees of this latent trait; and

(3) that it is valid to hypothesize both

   a. that teacher quality correlates with experience and not a lack of experience (e.g., having taken a college course in calculus is a better indicator of quality than not having taken such a course); and

   b. that higher levels of teacher quality correlate with higher levels of teacher responses on categorical questions (e.g., the response "not very well prepared" [to teach measurement (2000 Grade 8 Mathematics Teacher Questionnaire, Part II-A question 3b)] is higher than "not at all prepared," but "moderately well prepared"

[2] We did not apply this feature of IRT to the calculation of our scale of teacher quality.

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is higher than either, and "very well prepared" is the highest level indicator of quality).[3]

The application of IRT to teacher responses means that the teachers' background questions are treated in the same way as NAEP assessment items; however, instead of looking for "correct" answers, IRT is looking for hypothesized indicators of teacher quality. Thus IRT calculated a "difficulty" level for each question based on the proportion of quality indicators and the relationships among them (see Table 2). It also calculated for each teacher a probability of having the trait (or degree of the trait) measured by each question.

It is important to stress here that the use of IRT does not assume that IRT can "divine" what characteristics are of higher quality than any other nor does it *a priori* assume that the possession of any particular characteristics are a *prerequisite* for a quality teaching. Rather IRT merely determines the "difficulty" level of the various teacher characteristics examined, based on all teachers' responses. Thus the IRT-scale of teacher characteristics is not a frequency distribution of characteristics but rather the probabilities of each characteristic. Teachers who have said they have the most "difficult" characteristic can be considered "high quality" *not* because they have this particular characteristic *per se*, but because this characteristic is a marker for teachers who are most likely to have met the easier characteristics. This is to say, teachers who have completed professional development in calculus, for example, are not being rated as among the highest quality teachers on the IRT-scale because of the knowledge they gained in this particular professional development workshop but because such teachers turned out to be among those most likely to possess all other ("easier") characteristics. Thus the IRT-scaled characteristics should be properly thought of as markers rather than prerequisites of quality.

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[3] For this analysis, all categorical responses were coded so that the highest-level response is the highest coded value and the lowest-level response is the lowest coded value.

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Third, to test the hypothesis that better teachers are more likely to teach better scoring students, we regressed the IRT teacher quality scale on the subset of student and school characteristics shown to significantly affect student achievement in the first phase of this analysis. In order to do this, we used a marginal maximum likelihood (MML) regression. MML is a type of maximum likelihood estimation (MLE) useful for situations where the dependent variable cannot be expressed as a single value. This is the case with IRT because IRT does not calculate an individual's score but rather the probability of having each of the characteristics that partially measure the latent trait, which is to say it calculates a probability distribution over all possible teacher quality scores. The null hypothesis we tested was that all students are equally likely to be taught by teachers of the same quality. Our aim was to reject this by showing that students with characteristics correlating with higher or lower mathematics achievement (derived in step 1) make them more or less likely to be taught by a teacher of higher or lower quality (derived in step 2).

Results

1. Factors Influencing Student Achievement

The challenge of properly identifying factors correlated with student mathematics scores using a basic OLS regression model is to specify the model correctly. We estimated two models, a full model, using all the measures described above, and a restricted model. The results of both are displayed in Table 1. The restricted model (model 2) was trimmed based on the results of model 1, which regressed student mathematics scale scores on our full set of student, teacher, and school variables. We trimmed variables based on (1) their level of significance, (2) the degree to which they were related to the other exogenous variables, and (3) the degree to which they explain the overall variation in student math scores. By moving to the restricted model we avoid the potential problem that the percent of students receiving free/reduced price lunch and

the percent receiving Title 1 funding are likely to be highly correlated. A correlation matrix indicates that multi-collinearity is not a problem in the restricted model. Finally, given the small decrease in the R^2 between the first and second model and the fact that the second model is parsimonious, we will uses the restricted model in subsequent stages of this exploratory analysis.

Consistent with prior research, the results show that, with the exception of Asian/Pacific Islanders, minorities have lower scores than whites when all other factor are held constant. The largest differences are seen in the scores of blacks and Hispanics who score 23 and 16 points lower than whites respectively. Other results show that students with Individualized Education Plans (IEP), those who are classified as Limited English Proficient (LEP), and those eligible for free or reduced-price lunch score lower than their peers. Conversely, students enrolled in upper-level mathematics (e.g. Algebra, 2nd year Algebra, or Geometry) and those with at least one parent who is a college graduate score significantly higher than students enrolled in regular 8th-grade mathematics and those without a parent who is a college graduate.

2. Teacher Quality

The second step of our analysis used IRT to create a teacher quality scale based on the teachers' responses to a background questionnaire. Table 2 shows the scaled *b* parameters, or *difficulty* parameters, resulting from the IRT model. The characteristics scaled at the lowest difficulty parameter (–0.67) were "not very well prepared" to teach number sense, properties, and operations and measurement. The characteristics scaled at the highest difficulty parameter were professional development workshops for college algebra (1.77) and calculus (2.41). All other characteristics fell between these parameters. The placement of each teacher on this scale is related to the probability of the teacher having any given characteristic: teachers at any given score have a 50 percent probability of having the characteristic(s) at the same score, grater than 50 percent probability of having all characteristics below this score, and less than 50 percent

probability of having characteristics above this score. It is important to reiterate that these scores represent coordinates on a standard normal distribution curve (mean = 0, standard deviation = 1). The lower the score is, the more common (or "easier") the characteristic.

The Relationship Between Teacher Quality and Factors Influencing Student Achievement

By regressing the results of our IRT model on the subset of student and school factors determined to affect student achievement in the first phase of our analysis, we are able to implicitly examine the relationship between teacher quality and student achievement. The results of this regression are summarized in Table 3. They reveal that only a few variables are significant predicators of teacher quality. The coefficient on American Indians indicates that, when all other factors are held constant, they are less likely to be taught by an above average quality teacher than whites. The same is true for students with IEP's compared to students without; student in private schools compared to those in public schools; and students attending schools with high poverty (51-100 percent eligible for free/reduced price lunch) compared with students attending schools with low poverty (5 percent or less of students eligible for free/reduced price lunch). (The latter effect is most dramatic and most significant for students in schools where 76 – 100 percent of students are eligible for free/reduced price lunch compared with students in schools with low poverty.)

Conclusions

These results indicate that the null hypothesis—that teacher quality and student characteristics are unrelated—should be rejected. High quality teachers are not equally distributed among all students: students who are not American Indian, those who do not have an IEP, those enrolled in public schools, and those in schools with low poverty are all more likely to have high quality teachers than American Indians, students with IEPs, private school students, and students in high poverty schools. However, these results do not suggest a systemic pattern

that would support the conclusion that better teachers are moving to teach better-scoring students. Instead they suggest a simple pattern whereby higher than average quality teachers are found in more desirable teaching jobs: those not in remote areas of the country where American Indian reservations tend to be located, those without large numbers of students with IEPs, those in public schools (which generally pay higher salaries than private schools), and those not in high poverty schools.

Though hardly startling, these findings suggest the need to take a closer look at how teacher quality is distributed. In future analysis we plan to take into account teacher classroom practices as quality variables because it is highly likely that a teacher's classroom practices have a significant impact on student learning. The 2000 NAEP 8th-grade mathematics teacher background questionnaire collected information on classroom practices; however, to have including these data would have tremendously complicated this exploratory analysis. In addition, we plan to compare differences in the distribution of teacher quality and student achievement at the individual student level with those at the school level.

These findings also suggest that studies of the relationship of teacher quality and student achievement cannot assume that teacher quality is independent of student achievement scores. This is to say, besides controlling for prior student achievement and SES when trying to sort out the impact of specific teacher characteristics, such studies need to factor in the effect of high quality teachers being less likely to teach certain populations of low-scoring students.

Table 1. OLS regression results for 2000 NAEP 8th-grade mathematics scores.

	Model 1		Model 2	
Independent Variables	*Estimate*	*Standard Error*	*Estimate*	*Standard Error*
Constant	275.80***	5.66	271.55***	5.51
Teacher Factors				
Teaching experience: 2-years or less	-2.96*	1.74	-3.42*	1.90
Teacher certified but without math major	6.55***	1.86	6.57***	1.79
Teacher with math major but no certification	2.47	2.60	2.77	2.78
Teacher certified with math undergrad major	2.77	2.01	3.69**	1.88
Teacher certified with math grad major	2.93	2.13	4.10**	2.02
Teacher Confidence Index	0.48*	0.28	0.46*	0.25
Teacher Content Index	0.06	0.12	---	---
Teacher Preparation Index	-0.07	0.50	---	---
Student Factors				
Race: Black	-22.57***	1.63	-23.37***	1.65
Race: Hispanic	-13.66***	1.71	-15.75***	1.74
Race: Asian	8.43***	2.64	7.47**	2.81
Race: American Indian	-9.43*	5.00	-9.14*	4.82
Student taking Pre-Algebra	0.64	1.42	-0.88	1.47
Student taking Algebra/2nd year Algebra/Geometry	25.96***	1.72	24.66***	1.76
Student has Individualized Education Plan	-25.94***	2.64	-26.22***	2.69
Student classified as Limited English Proficient	-16.28***	3.81	-18.93***	3.71
Student eligible for free/reduced-price lunch	-7.27***	1.17	-7.39***	1.13
At least one parent is a college graduate	6.37***	0.78	6.37***	0.88
Student eligible for Chapter 1, Title 1 funding	-2.53	2.34	---	---
School Factors				
Private	-7.55***	2.20	-4.57**	1.99
6-25% of students eligible for free/reduced-price lunch	-5.81**	2.88	-1.55	3.10
26-50% of students eligible for free/reduced-price lunch	-13.64***	3.24	-9.40***	2.93
51-75% of students eligible for free/reduced-price lunch	-16.14***	3.45	-11.49***	3.24
76-100% of students eligible for free/reduced-price lunch	-21.54***	3.81	-15.63***	3.84
Region: Midwest	4.78**	2.24	---	---
Region: South	0.58	2.04	---	---
Region: West	-3.99	2.78	---	---
Locale: Mid-size city	-2.56	2.39	---	---
Locale: Urban fringe large city	-5.87**	2.12	---	---
Locale: Urban fringe mid-size city	-5.75**	2.48	---	---

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Locale: Large town	3.88	5.77	---	---
Locale: Small Town	0.47	2.80	---	---
Locale: Rural	-1.59	2.43	---	---
R^2		*0.437*		*0.425*
Root Mean Square Error		*26.52*		*26.88*

*Significant at the 0.1 level.

**Significant at the 0.05 level.

***Significant at the 0.001 level.

---Not used in model.

Note: Reference groups are 3 or more years of teaching experience; no math major/not certified; Race = white; 8th grade mathematics; no IEP; not LEP; not eligible for free/reduced-price lunch; no parent is college graduate; not eligible for Title 1 funding; Private; 0-5% of students eligible for free/reduced-price lunch; Northeast; large city.

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Table 2. IRT teacher quality scale

Teacher Response	*IRT quality score*
Number sense (not very well prepared)	-0.67
Measurement (not very well prepared)	-0.67
Data analysis, statistics, and probability (not v well prepared)	-0.66
Use of manipulatives (not very well prepared)	-0.65
Math problem-solving (not very well prepared)	-0.64
Algebra and functions (not very well prepared)	-0.63
Estimation (not very well prepared)	-0.62
Geometry and spatial sense (not very well prepared)	-0.61
Number sense (moderately well prepared)	-0.59
Measurement (moderately well prepared)	-0.50
Algebra and functions (moderately well prepared)	-0.44
Math problem-solving (moderately well prepared)	-0.44
More than 3 years teaching experience	-0.41
Studied problem solving in mathematics	-0.38
Geometry and spatial sense (moderately well prepared)	-0.38
Estimation (moderately well prepared)	-0.35
Data analysis, statistics, and probability (moderately well prepared)	-0.33
Studied use of manipulatives	-0.26
Certified, no major	-0.23
Use of manipulatives (moderately well prepared)	-0.14
College algebra (college course)	-0.12
Studied estimation	-0.07
Studied use of calculators in teaching mathematics	-0.05
Algebra and functions (very well prepared)	0.00
Number sense (very well prepared)	0.01
Probability/statistics (college course)	0.03
Calculus (college course)	0.04
Studied understanding of students thinking	0.09
Estimation (very well prepared)	0.10
Math problem-solving (very well prepared)	0.11
Geometry (college course)	0.14
Measurement (very well prepared)	0.14
Major, not certified	0.20
Studied teaching students from different cultural backgrounds	0.23
Geometry and spatial sense (very well prepared)	0.28
Data analysis, stats, (very well prepared)	0.31
Number systems (college course)	0.38
Studied gender issues in teaching math	0.40
Methods of elementary mathematics (college course)	0.40
Undergrad math major & certification	0.42
Measurement in mathematics (college course)	0.66

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Use manipulatives (very well prepared)	0.76
Measurement in math (professional development workshop)	0.85
Number systems (professional development workshop)	0.87
Methods of elementary mathematics (professional development workshop)	0.90
Geometry (professional development workshop)	0.96
Probability/statistics (professional development workshop)	1.04
Graduate math major & certification	1.24
College algebra (professional development workshop)	1.77
Calculus (professional development workshop)	2.41

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Table 3. Marginal maximum likelihood (MML) regression results for IRT teacher quality scale.

Independent Variables	*Estimate*	*Standard Error*
Constant	0.47***	0.141
Student Factors		
Race: Black	0.04	0.057
Race: Hispanic	-0.05	0.053
Race: Asian	-0.07	0.064
Race: American Indian	-0.43**	0.192
Student taking Pre-Algebra	0.06	0.048
Student taking Algebra/2nd year Algebra/Geometry	0.04	0.047
Student has Individualized Education Plan	-0.28***	0.073
Student classified as Limited English Proficient	0.10	0.079
Student eligible for free/reduced price lunch	0.01	0.029
At least one parent is a college graduate	-0.02	0.025
School Factors		
Private	-0.24**	0.101
6-25% of students eligible for free/reduced price lunch	-0.23*	0.140
26-50% of students eligible for free/reduced price lunch	-0.11	0.149
51-75% of students eligible for free/reduced price lunch	-0.23*	0.137
76-100% of students eligible for free/reduced price lunch	-0.38**	0.138
Root Mean Square Error		*0.73*

*Signficant at the 0.1 level.

** Significant at the 0.05 level.

*** Significant at the 0.001 level.

Note: Reference groups are Race = White, 8th grade mathematics, no IEP, not LEP, not eligible for free/reduced price lunch, no parent is college graduate, public, and 0-5% of students eligible for free/reduced price lunch.

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